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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3073

EXPERIMENTAL STRESS ANALYSIS OF STIFFENED
CYLINDERS WITH CUTOUTS

PURE BENDING

By Floyd R. Schlechte and Richard Rosecrans

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Langley Field, Va.

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SUMMARY

Bending tests were made on a cylindrical semimonocoque shell of circular cross section. The cylinder was tested without a cutout and then with a rectangular cutout which was successively enlarged through six sizes varying from 30° to 130° in circumference and from 1 to 2 bays in length. Strain measurements were made with resistance-type wire strain gages near the cutout on the stringers, the skin, and the rings for each size of cutout, and the stresses obtained are presented in tables.

INTRODUCTION

An experimental investigation of stresses in a semimonocoque circular cylinder with a cutout was discussed in reference 1 which gave results of the tests involving pure torsional loading. Another phase of the cylinder test is given in the present report, which contains stress data for the same cylinder loaded in pure bending with the cutout on the tension side of the cylinder.

Earlier experimental work on cylinders loaded in pure bending is given in references 2 to 4 where stringer strains and a limited number of shear strains are presented for a series of pure-bending tests of cylinders with cutouts.

TEST SPECIMEN AND PROCEDURE

Although the test specimen was the same one as that used in reference 1, a description of the cylinder is repeated here for completeness of the present paper. The test cylinder, which is shown in figure 1,

consisted of a 24S-T aluminum-alloy sheet covering of 0.051 inch in thickness, 36 external $3/4 \times 3/4 \times 3/32$ angle stringers of cross-sectional area of 0.1373 square inches, and 8 equally spaced, 24S-T aluminum-alloy Z-section rings of cross-sectional area of 0.4413 square inches. The rings were made of 1/8-inch sheet and were 2 inches deep with 1-inch flanges. The moment of inertia of the cylinder about a diameter was calculated to be 1119.3 in.⁴. After an initial test of the cylinder without a cutout, the series of cutout tests was begun with a cutout 1 bay in length by 30° in circumference. In four succeeding tests, the cutouts were 1 bay long and varied up to 130° in circumference. A final test was made with a cutout which was 2 bays long by 130° in circumference. The size of the cutout for each test is given in table 1.

The test procedure was analogous to that used in the torsion tests of reference 1. The cylinder was mounted on a heavy ring which was bolted to a rigid support. Load was applied to a steel bulkhead at the tip by means of a hydraulic jack acting on a loading frame. (See fig. 2.) In this figure, the cylinder is shown with the cutout sidewise, but for all tests included in the present report the cutout was down.

Baldwin SR-4 wire strain gages mounted near the cutout on the stringers, skin, and rings were used for obtaining all of the strain measurements. Type A-12 gages were used on the stringers and rings and AR-1 rosette gages were used on the skin. Typical gage mountings are shown in figure 3. Stringer gages were mounted either at the rings or halfway between rings along the inside corner of the stringer angle. Rosette gages were mounted either halfway between rings or $1\frac{1}{4}$ inches from a ring. In each rosette, two gages mounted at angles of 45° and 135° to the axis of the cylinder were used to measure the shear strain. Ring gages were placed near the neutral axis of the ring and on both flanges. The gage pattern in figure 4(a) shows the location of all the strain gages used in tests 2 to 6. The angular coordinate θ is measured from the center line of the cutout. All the gages shown were used in the test with a 30° cutout 1 bay long. For successive tests with a cutout 1 bay long, the cutout was enlarged by removing panels symmetrically located on either side of the longitudinal center line. All gages not cut away by enlarging the cutout were used in the next test. The gage pattern for test 7, with a 130° cutout 2 bays long is shown in figure 4(b).

In each test, the maximum load was chosen to make the most highly strained gage indicate tension or compression of about 10,000 psi. This was well below the buckling load in each test but was considered high enough to avoid the large relative errors associated with measurements of very small strains.

About 300 or 400 gages were read in each test, but the equipment available permitted only 80 gages to be read at one time. The procedure was as follows: A group of approximately 80 gages was read at each of four successively higher loads; then the first load was repeated as a check. If for some gages the original reading and the check reading differed by more than about 100 psi, the data for those gages were rejected and a test was performed for those gages only. Testing continued until satisfactory checks were obtained. If the temperature varied more than 1° F during a test run, the entire run was repeated. The reruns required only a small portion of the total testing time. After satisfactory data were obtained for a group of gages, another set of about 80 gages was read and the testing continued until all the gages had been read.

DATA REDUCTION AND ACCURACY

For each test, load was plotted against strain for the data from each gage, and the slope of a straight line through the test points determined the value taken as the strain at the maximum test load. Strains were converted to stresses with Young's modulus taken as 10,600,000 psi and the shear modulus as 4,000,000 psi. Tension is considered positive for normal stresses, and positive shear stresses are those that would be produced by a clockwise tip torque.

All results were referred to one quadrant because of symmetry; consequently, when possible, data from gages in various quadrants were averaged. The strain-gage layouts as shown in figure 4 indicate how much averaging was possible. The final stresses were all reduced to correspond to a bending moment of 180,000 in-lb, which was the maximum load for test 7.

Errors in measuring the applied load include an uncertainty of 1 percent in the jack load and a small amount of friction in the loading frame. In addition, the strain gages may have inaccuracies of 200 psi at the loads used in the tests or 3 percent, whichever value is larger. However, the agreement between results in four quadrants indicated that the strain-gage errors were usually considerably less than these amounts, and the results presented are better than individual gage data because of the averaging.

RESULTS

Stresses obtained for the six cutout tests are presented in tables 2 to 7, and the actual maximum load used in each test is also given.

Stringer stresses are given in part (a) of each table. An initial test of the cylinder without a cutout showed that the stresses were very close to values determined by elementary theory. Consequently, in all of the cutout tests, "stringer stresses due to cutout only" were calculated by subtracting the normal stress for no cutout, as determined by ordinary beam theory, from the measured stringer stresses. "Stringer stresses due to cutout only" are presented in part (b) of each table; shear stresses are given in parts (c); and the ring stresses are contained in parts (d).

General trends of the stringer stresses and shear stresses around the cutout are shown pictorially in figures 5 and 6. Stresses corresponding to the 30° cutout are given in figure 5 and stresses for the 90° cutout are given in figure 6. Each figure has three parts corresponding to sections (a), (b), and (c) of the tables. The test points, which are represented by the height of the heavy vertical lines, are joined by straight lines to give a pictorial view of the stress field. In the figures showing shear stresses, the lines joining points on opposite sides of the coaming stringer near the cutout have been broken because a straight line is not very accurate in this region.

CONCLUDING REMARKS

Stresses obtained in a series of pure-bending tests of a stiffened cylindrical shell with a cutout are presented in tables for six different sizes of the cutout. The data presented are intended primarily to serve as a check on methods of analysis or as a guide to the development of such methods. Consequently, no attempt has been made in this paper to interpret the data or draw conclusions therefrom.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., Dec. 10, 1953.

REFERENCES

1. Schlechte, Floyd R., and Rosecrans, Richard: Experimental Stress Analysis of Stiffened Cylinders With Cutouts - Pure Torsion. NACA TN 3039, 1953.
2. Hoff, N. J., and Boley, Bruno A.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. I - Experimental Investigation of Cylinders With a Symmetric Cutout Subjected to Pure Bending. NACA TN 1013, 1946.
3. Hoff, N. J., Boley, Bruno A., and Viggiano, Louis R.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. IV - Pure Bending Tests of Cylinders With Side Cutout. NACA TN 1264, 1948.
4. Hoff, N. J., Boley, Bruno A., and Mele, Joseph J.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. VII - Experimental Investigation of Cylinders Having Either Long Bottom Cutouts or Series of Side Cutouts. NACA TN 1962, 1949.

TABLE 1.- CUTOUT SIZE

Test number	Length of cutout, bays	Width of cutout, deg
1	None	None
2	1	30
3	1	50
4	1	70
5	1	90
6	1	130
7	2	130

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
480,000 INCH-POUNDS)

(a) Stringer stresses, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	+	-----					
		+	0	1,089		2,024	
	15	3,935	3,465	2,373		2,096	
		2,942	2,837	2,506		2,094	
		2,504	2,377	2,287		2,021	
	45	1,976	1,972	1,964		1,842	
		1,586	1,579	1,586		1,558	
		1,188	1,117	1,160	1,162	1,173	
	75	716	777	787		795	
		-167	-96	-157	-119	-93	
105							

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED

BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,

480,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg		+					
			-2,430	-1,341		-406	
	15	1,569	1,099	7		-270	
		713	608	277		-135	
		481	354	264		-2	
	45	218	214	206		84	
		148	141	148		120	
		114	43	86	88	99	
	75	37	98	108		116	
		5	66	5	43	69	
105							

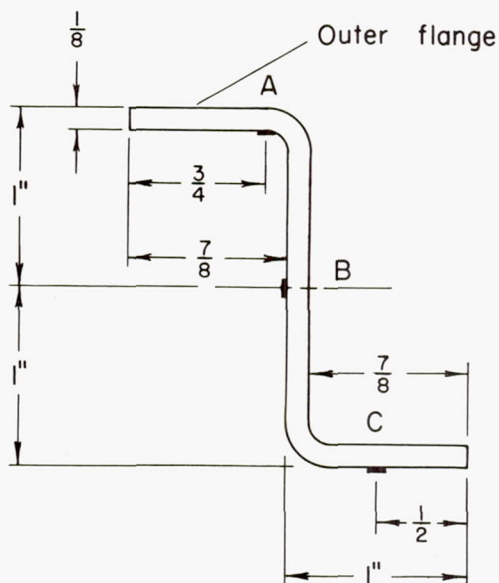
TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
480,000 INCH-POUNDS) - Continued

(c) Shear stresses, psi

		Distance from center line of cutout, in.							
		0	6	12	18	24	30	36	
	+		25	34					
			1,422	787		114		76	
15									
	-19	181	282	538					
	34	-153	76	125		127		153	
45									
	15	-93	-19	-53					
	-15	-51	-45	-104	35	41		137	
	-5	-49	-53	-147					
75									
	-3	-23	-31	-94	-104	-12	-38	-91	
	20	-30	-13		-51				
105									
	22	12	-4	-32	-6	31	-82	-167	
	26	23	-90		57				
135									
	65	28	-11			-5			
			-15						
165									
	48	43							

TABLE 2.- STRESSES AROUND CUTOOUT OF 30° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
480,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ , deg	A	B	C
5	-64	-401	-437
15	-283	-413	-161
25	-204	-230	15
35	-182	-55	40
45	-220	-66	138
55	-218	15	152
65	-205	21	147
75	-163	18	84
85	-113	0	0
95	0	0	0

TABLE 3.- STRESSES AROUND CUTOOUT OF 50° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
360,000 INCH-POUNDS)

(a) Stringer stresses, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	5,024	4,668	2,820		1,993	
	45	3,504	3,453	2,892		2,099	
	75	2,650	2,667	2,484		2,054	
		2,014	2,022	1,990		1,740	
		1,415	1,442	1,424	1,463	1,412	
		869	930	936		1,020	
		-192	-35	-148	0	24	
	105						

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED
 BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
 360,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	+	-2,430	-1,856		-776	
			-2,366	-1,262		-449	
		2,795	2,439	591		-236	
	45	1,481	1,430	869		76	
		892	909	726		296	
		576	584	552		302	
	75	341	368	350	389	338	
		190	251	257		341	
	105	-30	127	14	162	186	

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED

BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,

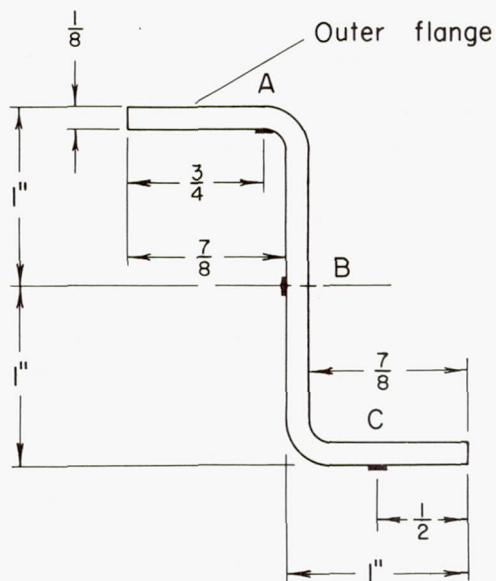
360,000 INCH-POUNDS) - Continued

(c) Shear stresses, psi

		Distance from center line of cutout, in.						
		0	6	12	18	24	30	36
θ , deg	15	+	24	29				
			562	710		237		84
			2,068	1,395				
	45	27	184	322	628		350	286
		68	-200	-41	-3			
		-12	-92	-148	-238	107	93	227
	75	27	-97	-209	-330			
		-21	-52	-163	-258	-266	-65	-99
		-21	-55	-146	-185			-78
	105							
		4	12	-29	-56	-33	-49	-119
								-192
	135	0	31	11	-64			
		52	25	10		27		
	165							
			0					
		41	47					

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
360,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ , deg	A	B	C
5	118	-800	-882
15	218	-501	-705
25	-134	-362	-104
35	-220	-10	234
45	-286	146	412
55	-368	216	484
65	-414	226	492
75	-380	143	390
85	-285	114	289
95	-210	72	156

TABLE 4.- STRESSES AROUND CUTOOUT OF 70° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
300,000 INCH-POUNDS)

(a) Stringer stresses, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	+	0	358		1,221	
			0	454		1,452	
			0	1,060		1,762	
		6,449	5,939	3,428		1,961	
	45	4,147	4,013	3,375		2,211	
		2,875	2,846	2,659		2,090	
		1,908	1,932	1,952	1,867	1,715	
	75	1,183	1,225	1,288		1,326	
		-57	50	-64	254	226	
	105						

TABLE 4.- STRESSES AROUND CUTOOUT OF 70° BY 1 BAY IN CYLINDER LOADED
 BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
 300,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
15	+		-2,430	-2,072		-1,209	
			-2,366	-1,912		-914	
			-2,229	-1,169		-467	
		4,426	3,916	1,405		-62	
		2,389	2,255	1,617		453	
45		1,437	1,408	1,221		652	
		834	858	878	793	641	
		504	546	609		647	
75							
		105	212	98	416	388	
105							

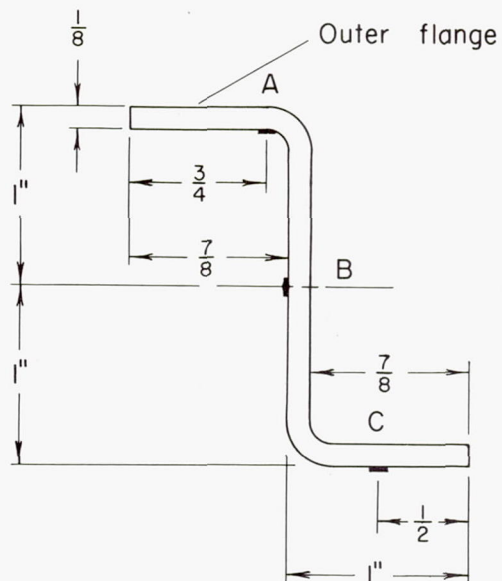
TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
300,000 INCH-POUNDS) - Continued

(c) Shear stresses, psi

		Distance from center line of cutout, in.						
		0	6	12	18	24	30	36
θ , deg	15	+	7	7				
			394	476		326		185
			870	1,056				
			2,641	1,634		570		424
	45	148	297	167	578			
		-49	-208	-236	-222	215	262	363
		22	-204	-408	-596			
	75	20	-122	-383	-480	-480	-119	-12
		25	-59	-344		-433		
105		15	7	-117	-155	-96	-115	-230
								-309
135		5	17	6		84		
165		27	42	17			-20	
				-57				
		42	74					

TABLE 4.- STRESSES AROUND CUTOOUT OF 70° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
300,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ , deg	A	B	C
5	463	-1,208	-1,442
15	401	-910	-1,160
25	331	-393	-641
35	-324	-88	292
45	-433	350	709
55	-569	521	900
65	-679	515	960
75	-673	376	814
85	-572	310	634
95	-355	149	394

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED
 BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
 240,000 INCH-POUNDS)

(a) Stringer stresses, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	+	0	175		848	
			0	265		1,044	
			0	437		1,362	
			0	1,286		1,852	
	45	7,791	7,233	3,975		2,131	
		4,690	4,610	3,808		2,332	
		2,806	3,011	2,918	2,461	2,168	
	75	1,678	1,880	1,896		1,761	
	105	24	283	56	493	532	

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED
 BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
 240,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	+	-2,430	-	-2,255		-1,582
			-2,366	-	-2,101		-1,322
			-2,229	-	-1,792		-867
			-2,023	-	-737		-171
	45	6,033	-	5,475	-	2,217	373
		3,252	-	3,172	-	2,370	894
		1,732	-	1,937	-	1,844	1,094
	75	999	-	1,201	-	1,217	1,082
		186	-	445	-	218	655
	105					694	

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED

BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,

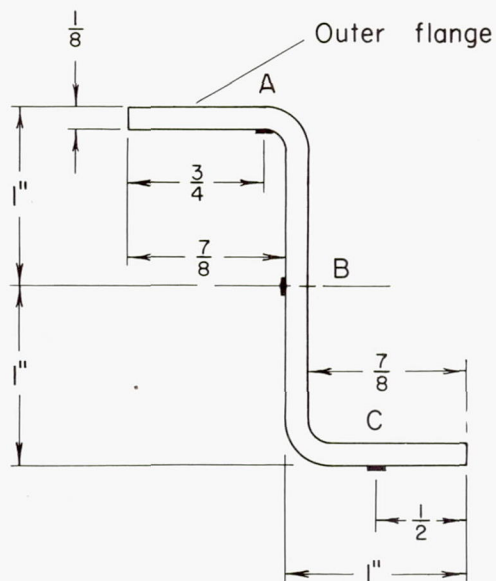
240,000 INCH-POUNDS) - Continued

(c) Shear stresses, psi

		Distance from center line of cutout, in.						
		0	6	12	18	24	30	36
15	+		56	9				
			314	269		309		210
			597	658				
			1,094	1,251		791		587
			3,088	1,826				
45		-15	358	-55	461	601	560	541
		154	-346	-576	-525			
75		83	-243	-645	-732	-677	-94	-124
		62	-122	-618		-649		
105		12	-25	-275	-315	-269	-244	-411
								-420
135		0	0	-40	90			
165		31	25	53		-22		
				83				
		77	62					

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
240,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ , deg	A	B	C
5	1,002	-1,491	-1,956
15	755	-1,192	-1,598
25	489	-713	-973
35	181	-10	-202
45	-662	226	896
55	-826	694	1,371
65	-908	884	1,546
75	-1,035	656	1,455
85	-922	592	1,171
95	-730	358	837

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
180,000 INCH-POUNDS)

(a) Stringer stresses, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	+	0	-11		257	
			0	71		410	
			0	156		661	
			0	368		1,120	
			0	618		1,682	
			0	1,852		2,424	
	45	10,918	10,346	5,448	3,334	2,675	
		5,936	5,973	4,982		2,751	
		1,166	1,617	1,299	1,993	1,744	
	75						
	105						

TABLE 6.- STRESSES AROUND CUTOOUT OF 130° BY 1 BAY IN CYLINDER LOADED
 BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
 180,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg		+					
15			-2,430	-2,441		-2,173	
			-2,366	-2,295		-1,956	
			-2,229	-2,073		-1,568	
			-2,023	-1,655		-903	
45			-1,758	-1,140		-76	
			-1,438	414		986	
		9,844	9,272	4,374	2,260	1,601	
75		5,257	5,294	4,303		2,072	
105		1,328	1,779	1,461	2,155	1,906	

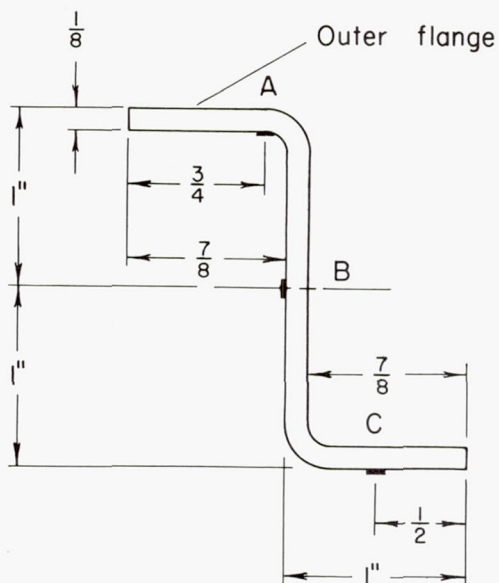
TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
180,000 INCH-POUNDS) - Continued

(c) Shear stresses, psi

		Distance from center line of cutout, in.									
		0	6	12	18	24	30	36			
θ , deg	15	+	47	-25							
			152	11		293		346			
			242	58							
			443	345		758		859			
			719	754							
			1,323	1,568		1,139	1,030		943		
			4,056	2,212							
	75	-	-140	379	-483	375	350	542	408		371
			-81	-476	-1,224	-820					
	105	-	-37	-169	-974	-1,046	-1,009	-667	-680		-531
	135	-	-70	-49	-422	-321					
165	-	16	-33	29			140				
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TABLE 6.- STRESSES AROUND CUTOOUT OF 130° BY 1 BAY IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
180,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ , deg	A	B	C
5	1,877	-1,804	-2,793
15	1,592	-1,516	-2,454
25	1,172	-1,214	-1,894
35	392	-684	-935
45	-368	-132	167
55	-734	959	1,208
65	-1,842	1,219	2,682
75	-1,945	1,537	3,037
85	-1,852	1,644	2,833
95	-1,614	1,290	2,292

TABLE 7.- STRESSES AROUND CUTOOUT OF 130° BY 2 BAYS IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
180,000 INCH-POUNDS)

(a) Stringer stresses, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	+		0	0		127
				0	35		297
				0	127		625
				0	293		996
				0	599		1,643
				0	1,639		2,236
	75		9,394	9,476	9,119	5,070	3,254
			5,989	5,986	5,830	4,839	2,883
	105		1,579	1,712	1,876	1,797	2,067
							1,908

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,
180,000 INCH-POUNDS) - Continued

(b) Stringer stresses due to cutout only, psi

		Distance from center line of cutout, in.					
		0	6	12	18	24	30
θ , deg	15	+		-2,430	-2,430		-2,303
				-2,366	-2,331		-2,069
				-2,229	-2,102		-1,604
				-2,023	-1,730		-1,027
				-1,758	-1,159		-115
				-1,438	201		798
	45	8,320	8,402	8,045	3,996	2,180	1,576
		5,310	5,307	5,151	4,160		2,204
		1,741	1,874	2,038	1,959	2,229	2,070
	75						
	105						

TABLE 7.- STRESSES AROUND CUTOOUT OF 130° BY 2 BAYS IN CYLINDER LOADED
BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,

180,000 INCH-POUNDS) - Continued

(c) Shear stresses, psi

Distance from center line of cutout, in.

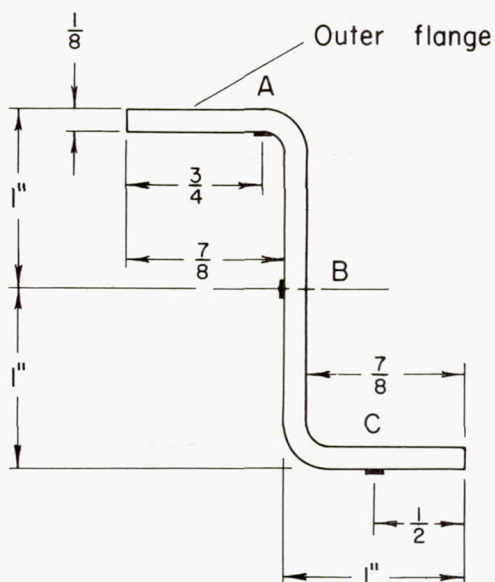
		0	6	12	18	24	30
θ, deg		+					
		-					
15				-124	8		
				99	22		449
				247	37		
45				389	271		989
				641	628		
				1,187	1,464	1,051	789
				3,693			
75		-118	231	672	-132	511	503
		164	21	-206	-865	-581	
105							
		84	-14	-177	-931	-1,030	-976
135		-21	0	-190	-507	-412	
		-144	-136	-148	-66		
165							
		-202					
			-21	-8			

TABLE 7.- STRESSES AROUND CUTOOUT OF 130° BY 2 BAYS IN CYLINDER LOADED

BY PURE MOMENT OF 180,000 INCH-POUNDS (ACTUAL APPLIED MOMENT,

180,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ , deg	A	B	C
5	1,961	-1,913	-2,856
15	1,696	-1,579	-2,544
25	1,128	-1,372	-1,881
35	498	-806	-1,034
45	-400	-90	180
55	-858	854	1,208
65	-2,242	1,018	2,750
75	-1,898	1,564	3,140
85	-2,008	1,558	2,740
95	-1,696	1,314	2,722

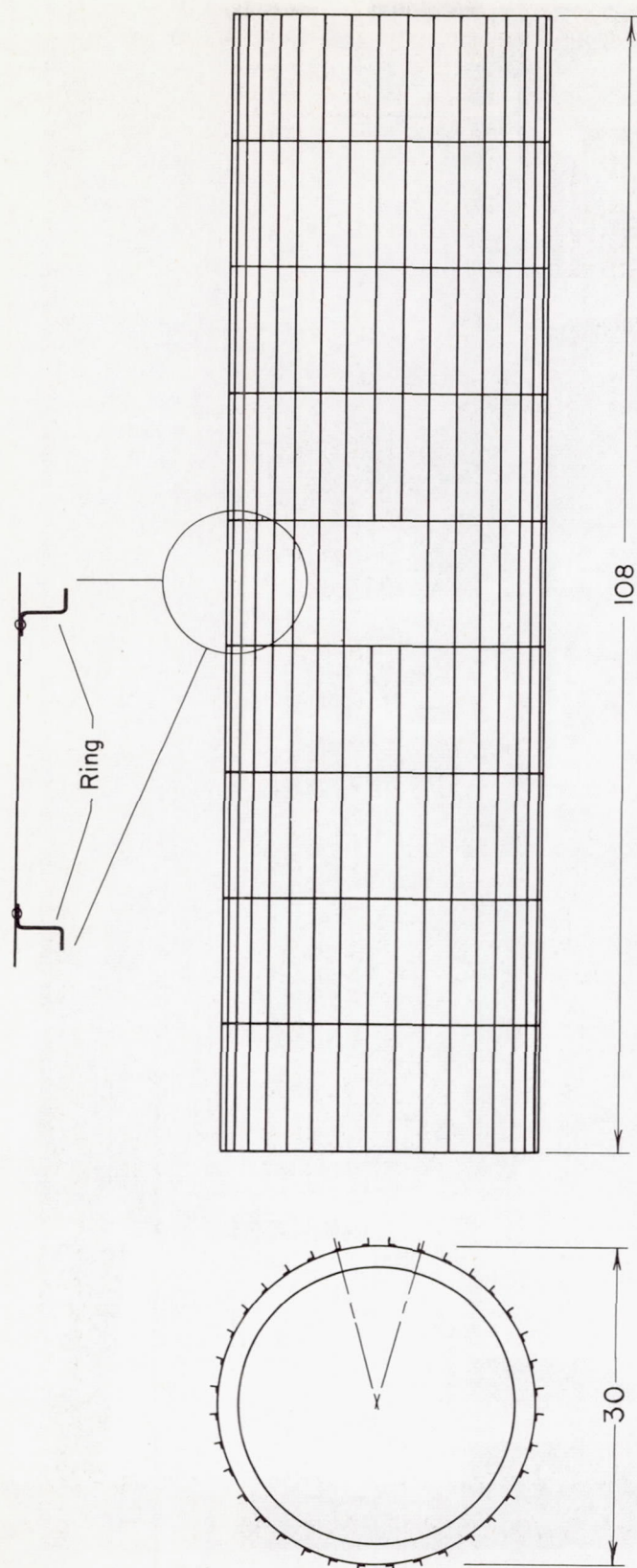
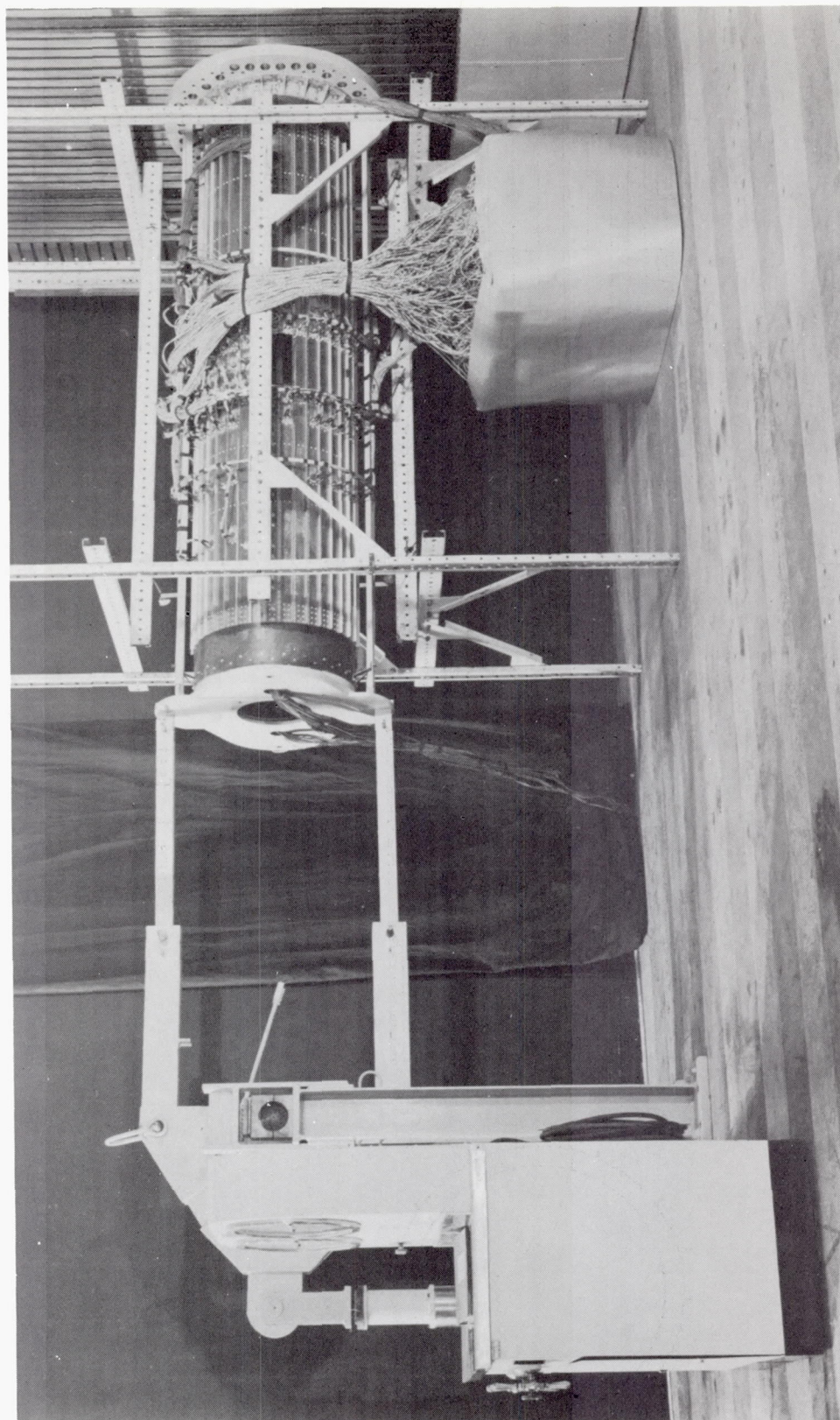
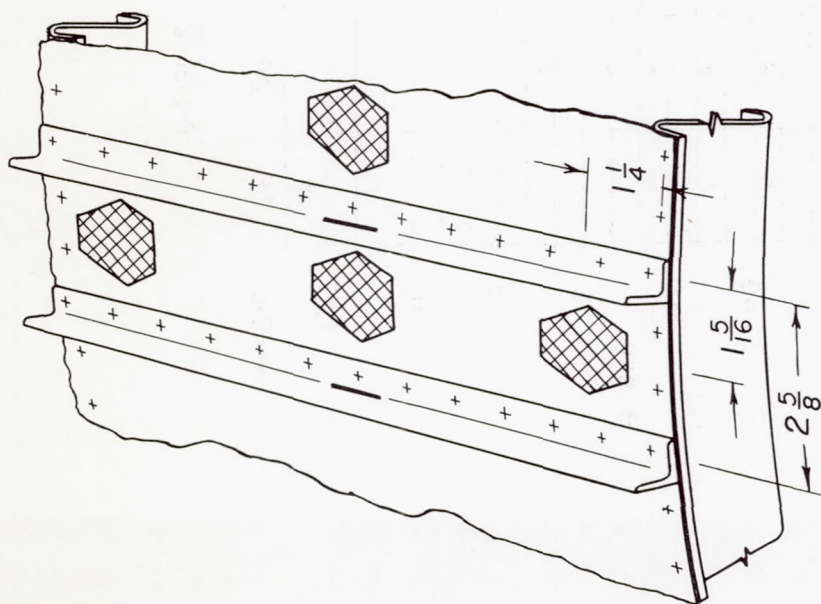


Figure 1. - Test specimen.

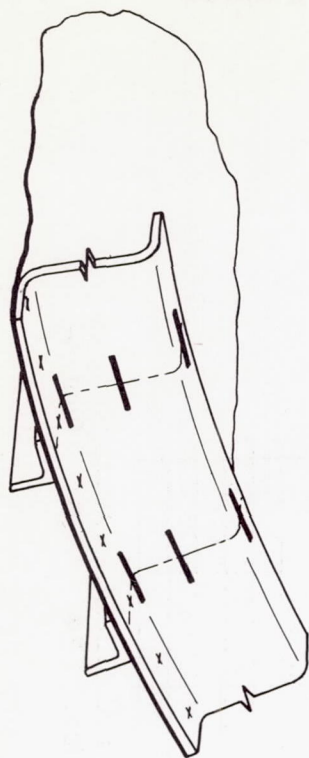


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Figure 2. - Loading system.

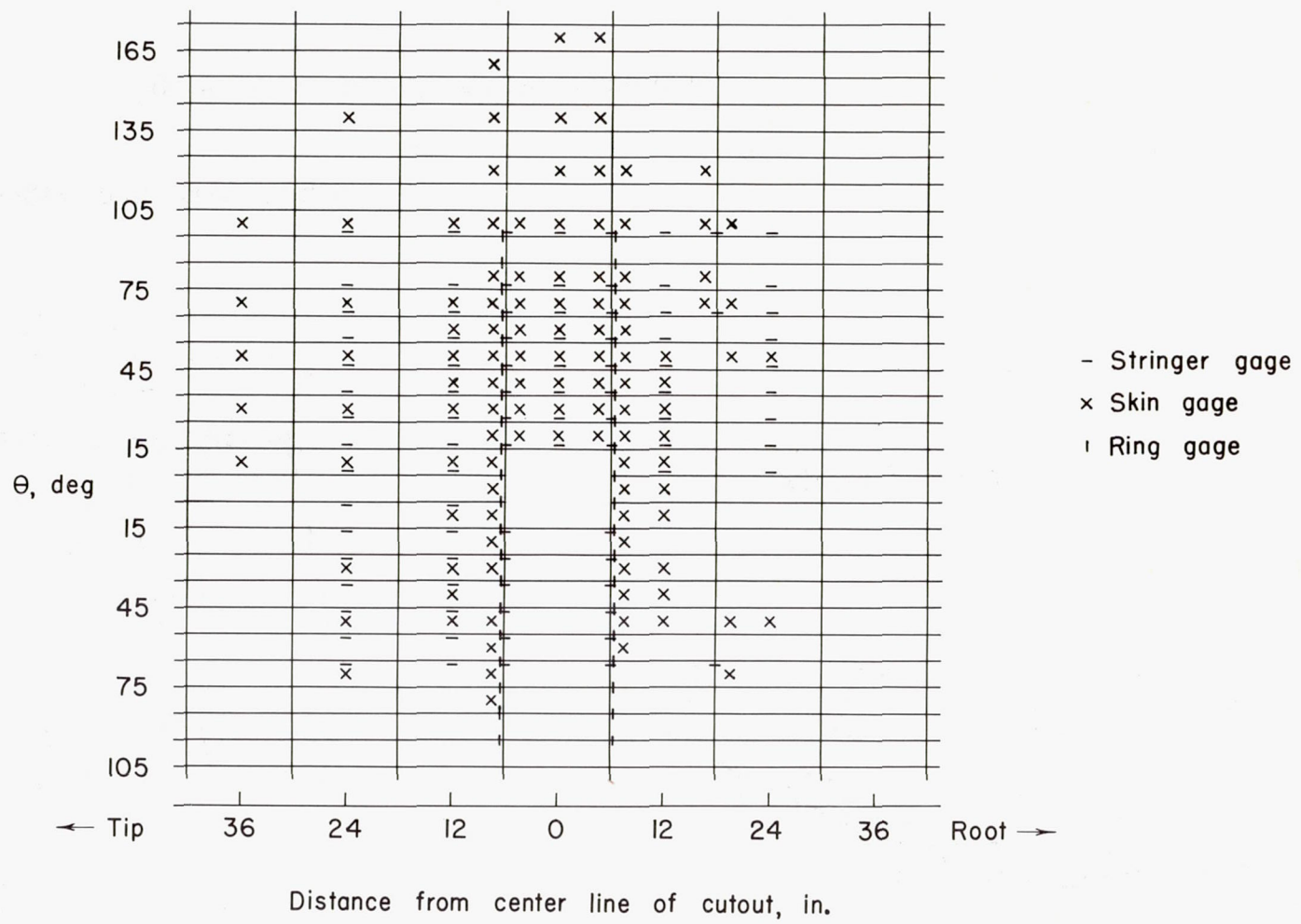


(a) Stringer and skin gages.



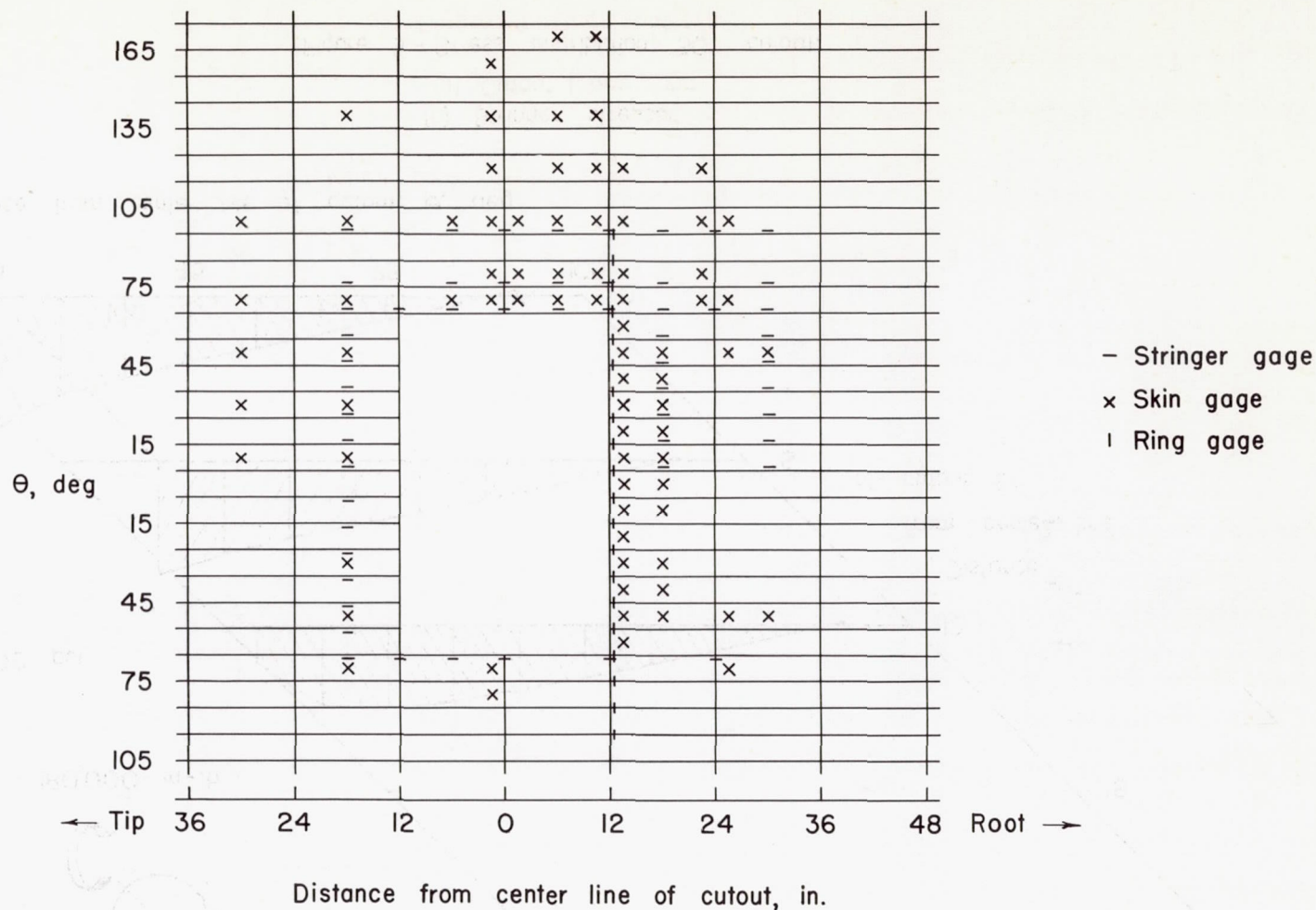
(b) Ring gages.

Figure 3. - Typical gage mountings.



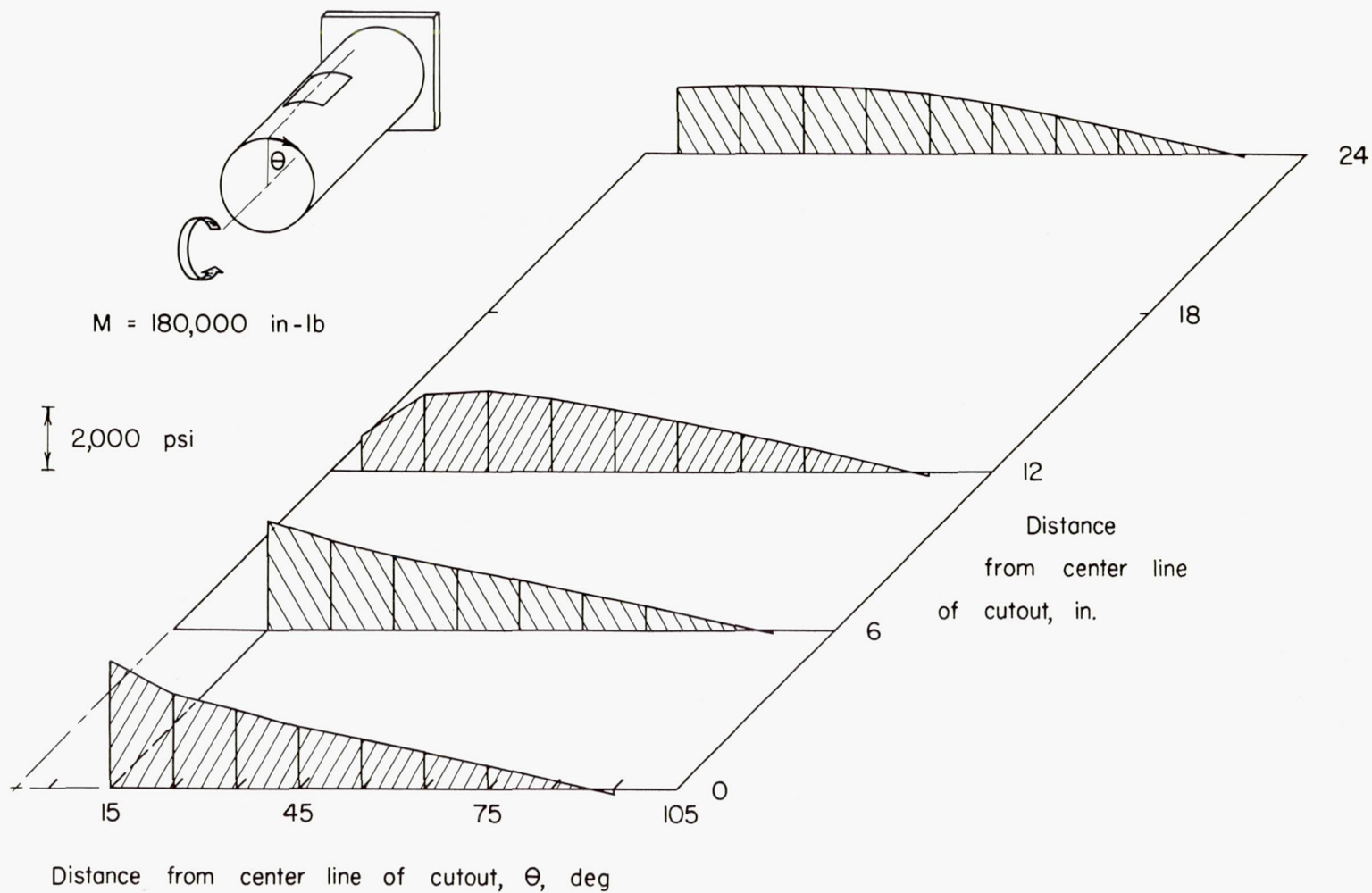
(a) Cutout 1 bay long.

Figure 4.-Gage pattern.



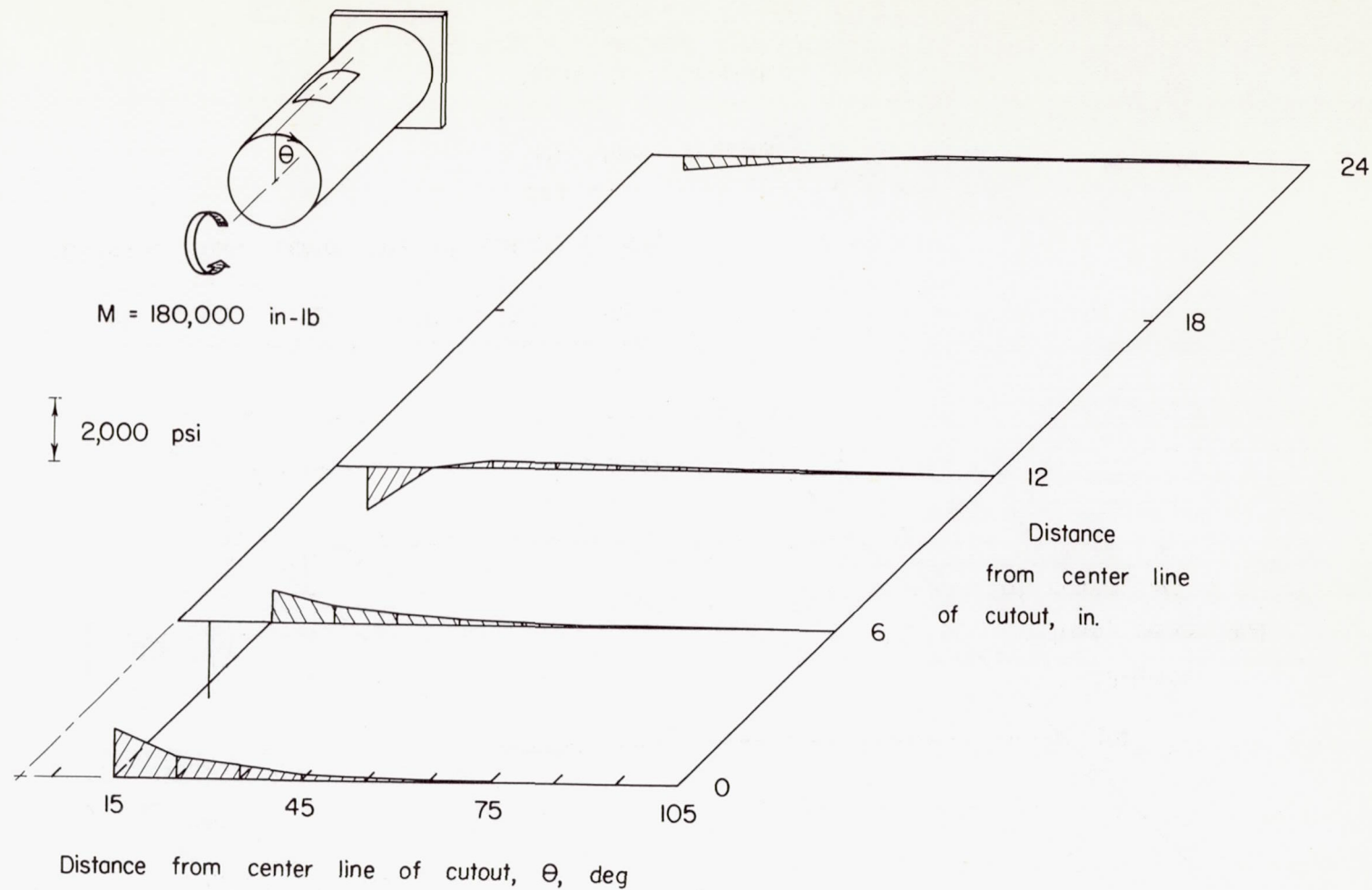
(b) Cutout 2 bays long.

Figure 4.- Concluded.



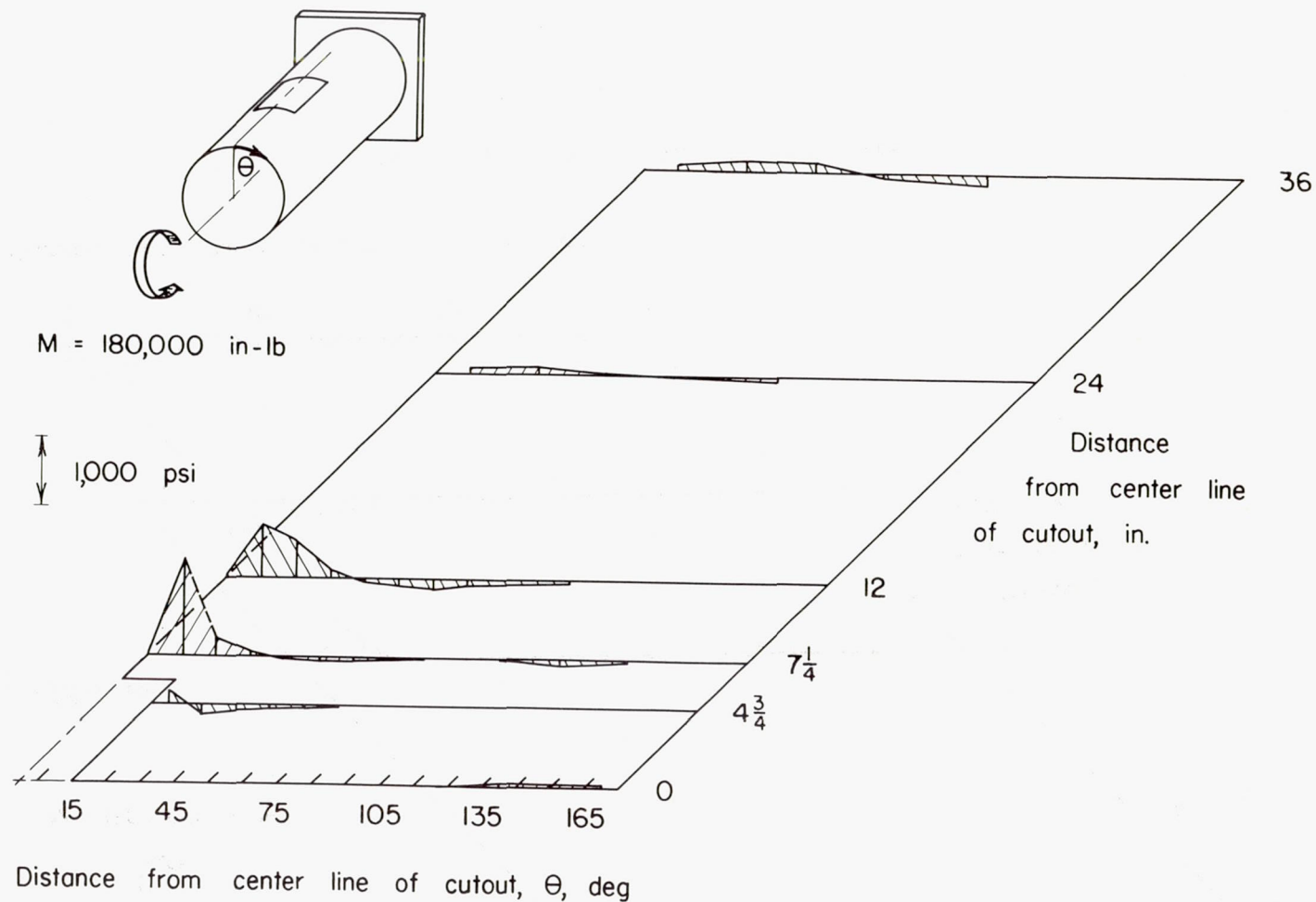
(a) Stringer stresses.

Figure 5.- Stress distribution, 30° cutout.



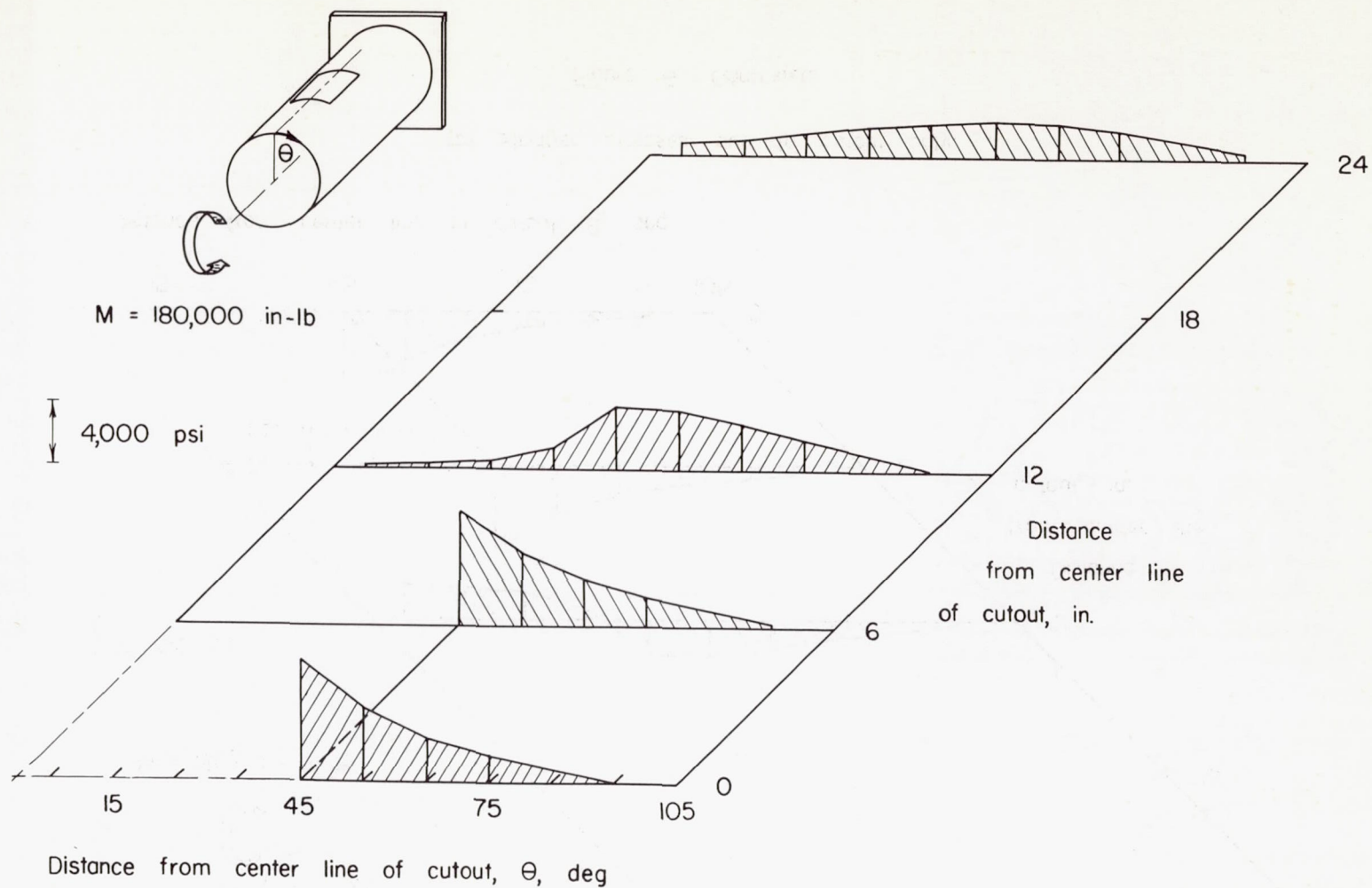
(b) Stringer stresses due to cutout only.

Figure 5. - Continued.



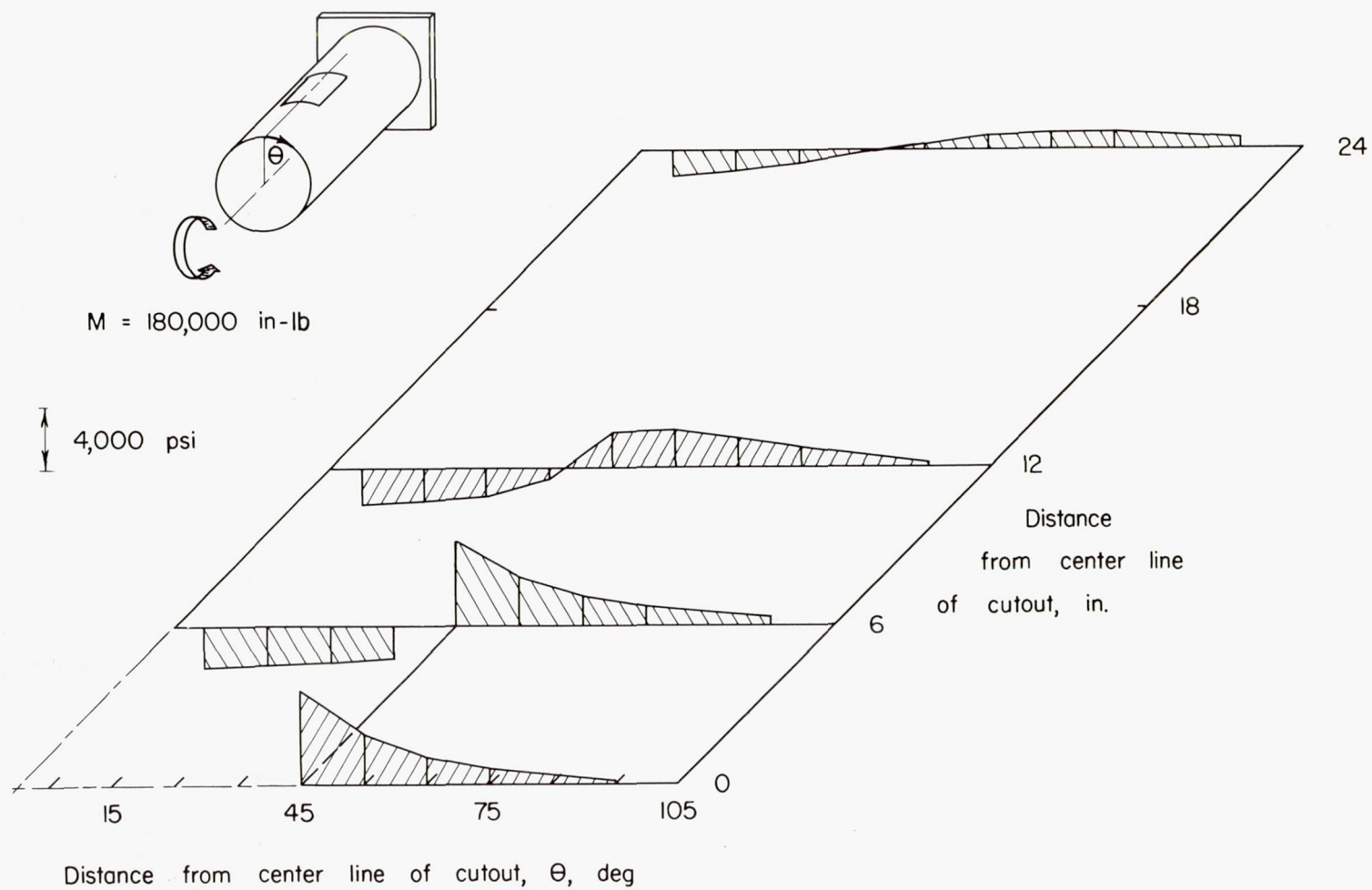
(c) Shear stresses.

Figure 5. - Concluded.



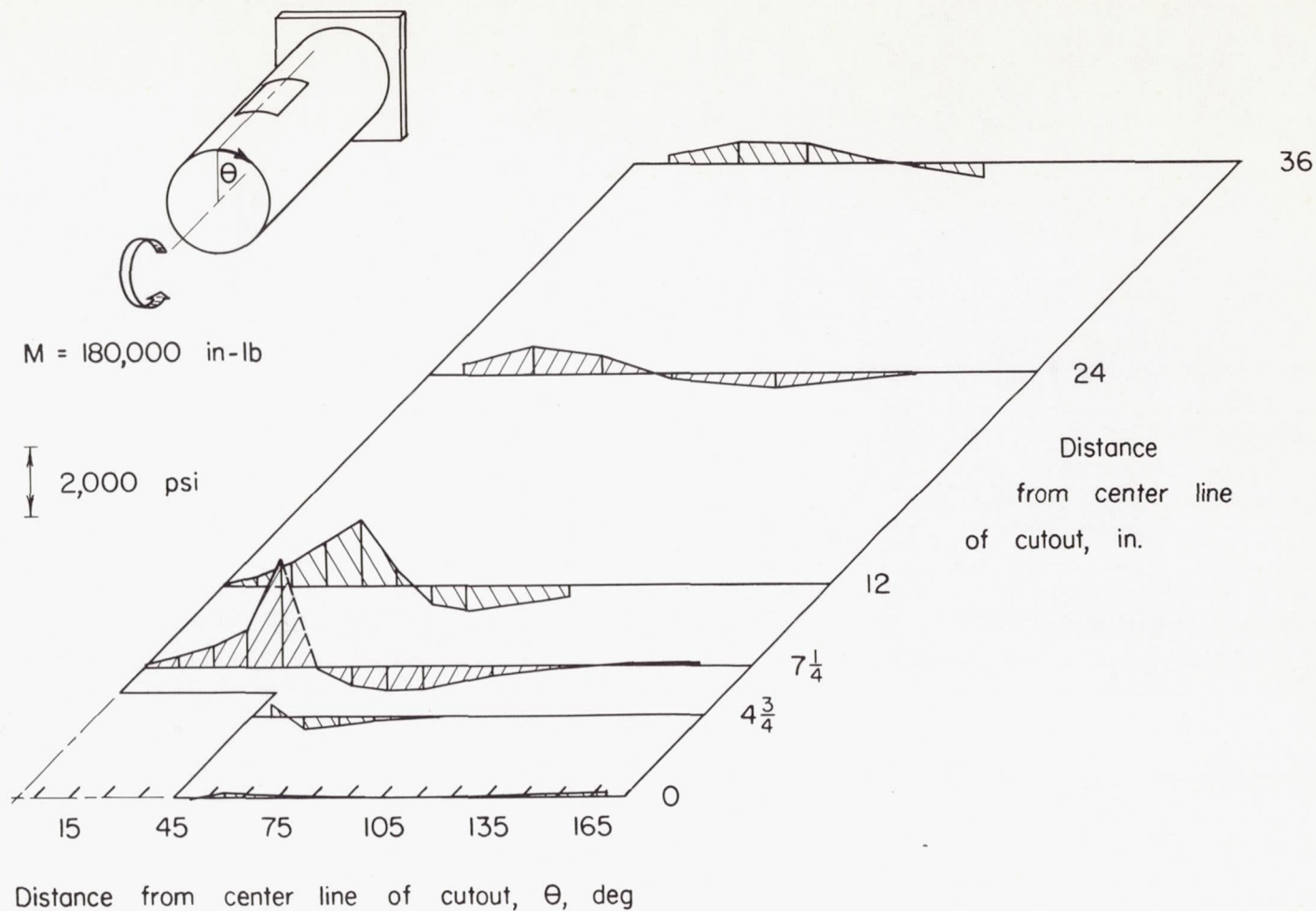
(a) Stringer stresses.

Figure 6. - Stress distribution, 90° cutout.



(b) Stringer stresses due to cutout only.

Figure 6. - Continued.



(c) Shear stresses.

Figure 6. - Concluded.